Performance Evaluation of Recharge Pits Method of Artificial Recharge of Ground water in Madhya Pradesh, India

V. K. Jain[1], Ajai Singh[2], O. P. Soni[3]

[1]Krishi Vigyan Kendra, RVS Krishi Viswavidyalaya, Ashok Nagar, M.P., India

[2]Regional Research Station (Old Alluvial Zone), Uttar Banga Krishi Viswavidyalaya, Majhian, Patiram – 733 133, Dakshin Dinajpur, West Bengal, India

[3]College of Agriculture, Khandawa, M.P., India

[2]ajai_jpo@yahoo.com/ajaiblg@gmail.com

Abstract

The significance of ground water recharge is a well known fact in the semi-arid region where the withdrawal rates are very high to fulfill the demand for irrigation. Recharge pits, made up of readily available materials, are a simple, cost effective and satisfactory method for recharging ground water storage where an impermeable layer does not allow natural charge of ground water. Recharge pits of rectangular shape (1.7 x 1.4m) with depth of 1.80 m were dug and constructed in series in a micro watershed of area 1.78 hectare in Nimar region of Madhya Pradesh, India. Experimental studies were conducted in 2003, 2004 and 2005 and results indicated that logarithmic equations were best fitted for determining the rate of ground water recharge in Eastern Nimar valley region. It was also observed that about 32.74% of runoff may be allowed for ground water recharge by adopting the method. The findings of the study may be adopted for planning and management of ground water by the different stakeholders in water scarce area or where ground water is becoming a scarce resource.

Keywords

Ground Water Recharge; Recharge Pits; Runoff; Nimar Valley; Madhya Pradesh

Introduction

Groundwater is an extremely important water resource, as it comprises more than 98% of the entire world's liquid fresh water (Bouwer, 1978). Natural recharge of groundwater is formed as the difference between water inputs into the soil in the form of precipitation and infiltration from streams, lakes, or other natural water bodies and outputs such as evapotranspiration, runoff and groundwater extraction. Natural recharge usually takes place about 30–50% of precipitation in temperate humid climates, 10–20% of precipitation in Mediterranean type climates, and about 0–2% of precipitation in dry climates (Tyler et al. 1996). Over exploitation of ground water for irrigation and other purposes, especially in dry climates, has led to irreversible consequences. The growing population, rapid industrialization and increased agricultural production in numerous countries require more and more water of adequate quality. In many regions there is a lack of surface water and severe water contamination. Shallow groundwater resources are often of insufficient quality and over-exploited. Therefore, it is of high priority to take into consideration all the proved water techniques that could help to reduce the existing disaster. To meet the demand, reliance on ground water has been rapidly increasing, especially, in the arid and semi-arid regions like India, where the current ground water potential (43.2 M ha-m) needs to be judiciously utilized (Singh, 1997). Although artificial groundwater recharge methods have been extensively used in the developed nations for several decades, their use in developing nations, like India, has occurred only recently.

The ground water table is declining at a very fast rate in arid and semi-arid zones in India. In some places it has gone beyond at such a depth below ground that it is not economical to pump water for irrigation and even drinking purposes and Government has banned digging of ground water extraction mechanism in considerable number of Blocks (administrative unit) in India. If the ground water extraction is more than ground water removal, then the question of artificial recharge system brings out. Artificial recharge systems

are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources. Other objectives of artificial recharge are to reduce seawater intrusion or land subsidence, to store water, to improve the quality of the water through soil-aquifer treatment and to use aquifers as water conveyance systems. Infiltration and artificial recharge are achieved by ponding or flowing water on the soil surface with basins, furrows and ditches, etc.; by placing it in infiltration trenches, shafts, or wells; or by placing it in wells for direct injection into the aquifer. Other forms of groundwater recharge include natural, enhanced, induced, and incidental recharge (Bouwer, 2002). Enhanced recharge consists of vegetation management to replace deep-rooted vegetation by shallow-rooted vegetation, so that the plants intercept less precipitation with their foliage and thus increasing the amount of water that reaches the soil. Induced recharge is achieved by placing wells relatively close to streams or rivers, so that more river water is pulled into the aquifer as water tables near the streams are lowered by pumping the wells (Kuhn, 1999). Another form of recharge is obtained with urbanization, during which most of the land is covered with streets, pacca road, roofs, and other impermeable surfaces that produce more runoff and have much less evapotranspiration than the natural surfaces. With urbanization, more runoff is produced, which can be collected for on-site storage and artificial recharge, or it flows naturally to ephemeral streams where it infiltrates into the soil and moves down to the groundwater (Lerner, 2002). Artificial recharge is expected to become necessary in the future as growing populations require more water, and as more storage of water is needed to save water in times of water surplus for use in times of water shortage.

To fully utilize the ground water potential and to plan and design the artificial recharge system, an accurate measurement or account of water recharge into the ground is necessary. Many researchers have developed methods and procedures for estimating ground water recharge (Harpaj, 1971, Athavale and Rangarajan, 1988, Johnson, 1987, Sharma 1987, Rai et al., 1997). These include the use of base flow hydrograph, hydrologic budgeting /water balancing, empirical models, ground water level fluctuation method, two dimensional and three dimensional ground water hydrological models. Sophocleous (1991) proposed a relatively simple and practical approach which combined the soil moisture balance methods with water level fluctuation methods to estimate natural recharge estimation. Hari Prasad et al. (2005) developed a simple model for assessment of ground water recharge by solving the Richard's equation. The artificial recharge of ground water through scientifically designed structures has proved to be a viable option for augmentation of ground water resources and provides an opportunity to store the excess rainfall during monsoon periods of June – September in India. The choice of a particular method is governed by local topographical, geological and soil conditions; the quantity and quality of water available for recharge; and the technological-economical viability and social acceptability of such schemes. A combination of field, laboratory, analytical, and simulation methods generally is used to develop an understanding of the hydro-geological system as a basis for predicting potential consequences. Optimization techniques may be coupled with predictive models of ground-water flow and other processes to create an effective tool for planning and management of artificial recharge projects. Pre-project and long-term monitoring of key aspects of a flow system is an essential part of a successful management plan. Of all the factors in the evaluation of groundwater resources, the rate of recharge is one of the most difficult to derive with confidence. Estimates of recharge are normally subject to large uncertainties and spatial and temporal variability.

The Government of India constituted a committee named as Ground Water Estimation Committee which recommended the use of ground water table fluctuation method for sufficient accuracy. The sub-surface techniques of ground water recharge usually are applied to recharge the deep aquifers overlain by impermeable layers. The most common methods used for recharging such deep aquifers are a) Injection or recharge wells, b)Recharge pits and shafts, c) Dug well recharge, d) Bore well flooding and e) Recharge through natural openings and cavities. The hydraulic properties of an aquifer system, along with the distribution of stress, determine the direction and rate of saturated flow. Given the distribution of head, stress, and hydraulic properties, simulation models can be developed to help address the fate of artificially recharged water and off-site effects. Monitoring and simulation are both used to address off-site effects; however, simulation can also be used to design an efficient monitoring network prior to full-scale implementation. The study of performance evaluation of the above methods under actual field conditions has

rarely been undertaken for the region taken up in the current project. In the present study, attempts were made to quantify the rate and volume of ground water recharge through the Recharge pits method using simulation techniques at micro watershed level.

Materials and Methods

Description of Study Area

In the present study, the Nimar region of Madhya Pradesh, India was undertaken which is bounded by latitudes of 200^0 40′ N to 220^0 50′ N and longitudes of 740^0 42′ E to 770^{0}20' E. Nimar is the southwestern region of Madhya Pradesh state in west-central India. The region locates at south of the Vindhya Range, and consists of two portions of the Narmada and Tapti river valleys, separated by a section of the Satpura Range, about 24 km in breadth. The average elevation of the command ranges from 200 to 500m from the mean sea level. Major part of the region lies on upland between the valley of the Narmada and the Tapti rivers. A compact dense layer of soil or hard pan at shallow depth generally limits the entry of infiltrated water in vertical direction. Location of the study area is given in Fig. 1.

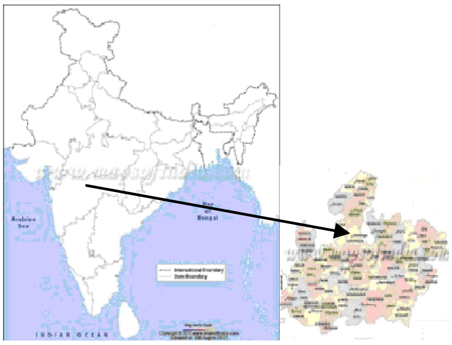


FIG.1. LOCATION MAP OF NIMAR REGION IN MADHYA PRADESH STATE OF INDIA

Construction and Installation of Recharge Pits

Recharge pits are structures that overcome the difficulty of artificial recharge of phreatic aquifer from surface-water sources. Recharge pits are excavated on variable dimensions that are sufficiently deep to penetrate less permeable strata. A recharge shaft is similar to a recharge pit but much smaller in cross-section. Recharge pits of rectangular shape (1.7 x 1.4m) with depth of 1.80 m were dug and constructed in series in a micro watershed of area 1.78 hectare. The down stream part of the micro watershed passes over a tube well. These pits were filled with gravels (10 to 50 mm size) and sand in layers of almost equal thickness, respectively, from top to bottom. The depth of each layer was maintained as 60cm in all the pits. The porous media made of gravel-sand-packed (GSP) in pits filter the contaminated and dirty runoff water so as to percolate cleaned water for ground water recharge. In the presented study, two GSP recharge pits were selected named '*A*' and '*B*' and these were located at 38 m and 5.90 m away from the tube well towards up-stream side of the watershed. The capacity of recharge pits 'A' and 'B' to store water for ground water recharge was determined as 1600 and 1570 liters with the help of information on void ratios as 0.38 and 0.40 for recharge pits A and B, respectively. Piezometers were installed in the recharge pits at its one corner before filling gravel and sand for recording the depth of water table. The observation on water table in the piezometer was collected daily at 8.00 A.M. and 5 P.M. during rainy season. Water table in the tube well was also recorded. Measuring tape with sounding device was used for locating and measuring water table depth below ground surface. Seasonal rainfall of 697, 652 and 671 mm were received in 56, 52 and 55 rainy days during the years 2003, 2004 and 2005, respectively.

The depth of ground water table was recorded as soon as the water table appeared in the piezometer. The trend of ground water table lowering down with respect to number of days passed in rainy season (DPRS) was analyzed by applying regression techniques. Three types of regression equations viz. linear, power and logarithm were tried and developed in this study. The estimated values of ground water table depth were computed using regression equations and are given in Table 1 for the year 2005 along with observed data. The best fitted equation was selected to determine the rate of ground water recharge through the pit for longer period. Recharging tests were carried out by applying known discharge of water to recharge pits *A* and *B* under artificial flow condition for simulation of ground water recharge. The depth of water table was recorded in two phases. In the first phase, the rising trend of water table showed the filling rate of water in the pits after allowing certain percentage for ground water recharge. In the second phase, when the pit was filled completely with applied water, the application of water was cut off. The observed depth of ground water table was due to ground water recharge only. Similar types of regression equations as developed under natural flow conditions, were fitted for the depth of water table with respect to time passed during both the phases of

testing i.e. water application along with recharging phase and water recharging alone phase.

Result and Discussion

Ground Water Recharge Rate

The surface runoff started only when the entire field was saturated and it was observed that the surface water flow occurred normally after receipt of cumulative rainfall of 80 to 100 mm during the rainy season. It was also observed that surface flow visualized only for few days during the entire season. Observed data for ground water table depth were regressed over the number of days passed after rainfall in order to achieve uniformity of the curve. Linear, power and logarithmic nature of regression equations were fitted for estimation of depth of water table in recharge pits *'A'* and *'B'* for the year 2003 to 2005 as given in Annexure I.

The depths of ground water table were estimated by using all the three types of equations and are given from Table 1. It is evident from the table that the estimated values of depth of ground water table in both the recharge pits given by power and logarithm equation are close to the observed values. Since the power equation was of exponential nature, the logarithm type of equation was preferred, particularly for initial and delayed period of recharge. Selected logarithmic regression equations were further used to determine the rate of ground water recharge and are presented in Fig. 2. It is revealed from the figure that initially the rate of ground water recharge was higher. The estimated rate of recharge was found to be reduced as the days passed after rainfall. Gradually the rate of recharge slowed after 20 days of occurrence of rainfall. Rates of percolation were high in the beginning of the rainy season, but diminished thereafter mainly due to the accumulation of silt in the bottom of the recharge pits. Periodic de-silting, therefore, was determined to be an essential element in the maintenance of these pits. The mean values of estimated rates of recharge were decreased from 11.07 (5 days) to 0.86 (20 days) mm/hr in recharge pit *'A'* and 8.65 (5 days) to 0.94 (20 days) mm/hr in recharge pit *'B'*. Since the soil type was the same with the entire field, the overall mean values of estimated rate of ground water recharge was taken as 9.86, 2.96, 1.34 and 0.99 mm/hr for first 5, 10, 15 and 20 days, respectively, after the rainfall stopped.

Quantification of Ground Water Recharge

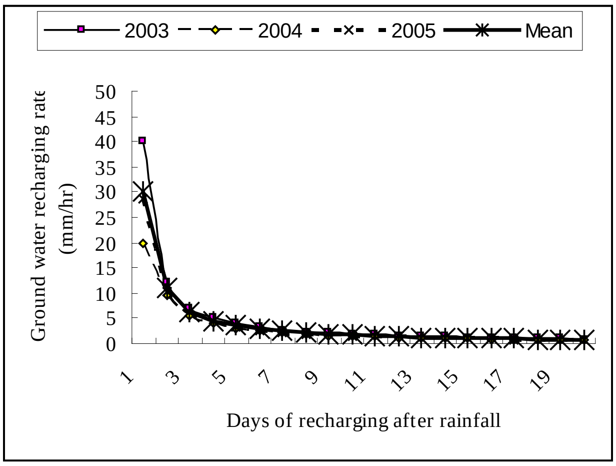
In order to determine the quantity of ground water recharge in terms of fraction of rainfall, runoff simulation tests under artificial flow condition were carried out. In the first phase, observed depth of ground water table with respect to time passed since volume of water was applied, were recorded. In the second phase, the observed depths of ground water table, due to recharge only, were observed. The regression equations were fitted for both the phases as (i) $D = A1 + B1\ (T)$, (ii) $D = A2+B2\ (T)$ and (iii) $D = A3+B3 \ln (T)$. Regression coefficients and other properties of regression equation for estimated depth of ground water table (D in cm) with respect to time (T in hour) passed since the time at which applied water and recharged water are given in Annexure II.

Logarithm nature of regression equations were found as the best amongst the other regression equations, hence selected for estimation of depth of ground water table. Estimated values for artificial flow condition test conducted on different dates for both the pits were computed with respect to time passed. The percentage of flow of stream as water recharge were found 27.92, 33.96, 36.84 and 41.88 for artificial flow condition tests for the recharge pits conducted on 25th, 26th and 27th October 2005, and 28th October 2004, respectively. The reason for different percentage for recharge pit *'A'* and pit *'B'* may be due to different saturation status in the porous media of the pits. However, an average percentage value of 37.56 for recharge pits *'B'* was taken. Only the results of the test conducted on 28th October 2004 for recharge pit *B* are given in Table 2. The details of the conducted test are given in Annexure II. The soil type is same throughout the micro watershed, hence an average percentage of the value 32.74 (Average of pit *'A'* and pit *'B'*) was adopted for ground water recharge as the percentage of water applied or runoff received by the recharge pits.

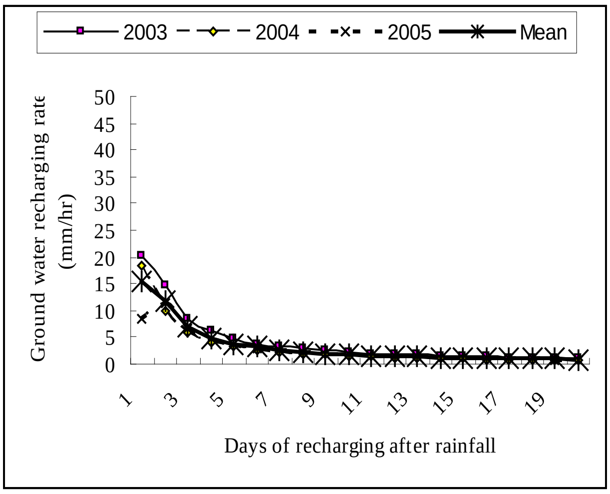
Seasonal ground water recharge

Estimated rate of ground water recharge under natural and artificial conditions of flow was compared. The data presented in Table 3 revealed that the percent deviation from natural flow condition test over the artificial flow condition test was higher during the first day of recharging while it became smaller for the remaining 2 to 10 days in both the recharge pits.

However, the deviation was more in recharge pit *A* in comparison to pit *B*. The mean deviation in recharge rates taking together for pit *A* and pit *B* was almost constant as depicted from Table 3. The main cause for lower percentage of recharge rate under artificial flow condition may be the lower stream size of applied water and uneven distribution of moisture in the porous media of the pits. Hence variation in recharge rates under artificial flow condition was justified. Therefore, the overall mean rate of ground water recharge under natural conditions of rainfall was adopted for the soil type in the region. Estimation of volume of ground water recharge depends on the percentage of water application or stream flow towards the recharging pits as shown in Table 3. The average value of 32.74% of stream flow/runoff near the recharge pit from the watershed was adopted for the soil type in the micro watershed.



(a)



(b)

FIG. 2. ESTIMATED RATE OF GROUND WATER RECHARGING THROUGH RECHARGE PITS A (a) AND b (b) USING LOGARITHM REGRESSION EQUATION

Conclusions

Gravel-sand-packed recharge pits are very simple in construction as the materials required for construction are locally and readily available. It was estimated that 32.74% of total stream flow/runoff received in a season may be allowed for ground water recharge using the recharge pits. A number of Gravel-sand-packed recharge pits, if constructed in series on the waterway of micro watershed, may lead to achieve good amount of ground water recharge.

REFERENCES

Athavale, R. N., and R. Rangarajan. "Natural recharge measurements in the hard rock regions of semi-arid India using tritium injection: A review" In Estimation of Natural Ground Water Recharge, edited by I. Simmers, 175-194. Boston: D. Reidal Public Co. Dordrecht, 1988.

B Singh "Water resources development in India - a perspective." In Proc. International Symposium on Emerging Trends in Hydrology, Deptt. of Hydrology, University of Roorkee, Roorkee, India 1(1997): 1-17.

D N Lerner "Identifying and quantifying urban recharge: a review" Hydrology Journal 10(2002), 143-153.

H, Bouwer. Ground water hydrology. New York: McGraw-Hill, 480, 1978.

H, Bouwer. "Artificial recharge of groundwater: hydrogeology and engineering." Hydrogeology Journal 10 (2002): 121–142.

Hari Prasad, Mohan Kumar, Sekhar, and B. Chandrasekhar. "A simple numerical model for assessment of groundwater recharge." J. IWRS 25.1 (2005) :49-60.

Krishnamurthi, Sunada, and R A Longenbaugh "Mathematical modeling of ground water recharge." Water Resource Research 13.4(1977): 720-724.

M A Sophocleus "Combining the soil water balance and water level fluctuation methods to estimate natural ground water recharge: Practical aspects." Journal of Hydrology 124(1991):229-241.

M L. Sharma "Measurement and prediction of natural ground water recharge - an over view." Journal of Hydrology (N.Z.) 25(1987): 49-56.

P O, Johnsson "Estimation of ground water recharge in sandy soil with two different methods using ground water level fluctuations." J. Hydrology 90(1987): 183 198.

Rai, Ramana, and A. Manglik "Modelling of water table fluctuation in a finite aquifer system in Symposium on Emerging Trends in Hydrology." Deptt. of Hydrology, University of Roorkee, Roorkee, India 1(1997): 243-250.

Tyler, Chapman, Conrad, Hammermeister, Blout, Miller, Sully, and J M Ginanni "Soil-water flux in the southern Great Basin, United States: temporal and spatial variations over the last 120,000 years." Water Resources Research 32.6(1996):1481–1499.

W Kuhn "Overview of riverbank filtration issues." Proc Int Riverbank Filtration Conf, Louisville, Kentucky, USA, sponsored by Nat Water Res Inst, Fountain Valley, California, USA, 1–4, 1999.

Y, Harpaj "Artificial ground water recharge by means of wells in Israel." J. Hydraul. Div., Proc. ASCE 12(1971): 1947-1964.

TABLE 1 ESTIMATED DEPTH OF WATER TABLE IN RECHARGE PITS (2005)

DPRS, days	Rainfall, (mm)	Observed Depth, (cm)		Estimated Depth by Regression Equation, (cm)					
				Linear		Power		Logarithm	
		Pit A	Pit B	Pit A	Pit B	Pit A	Pit B	Pit A	Pit B
48	1.0	73	25	78.09	30.23	72.54	26.31	68.86	20.08
48.25		80	31	80.91	33.28	78.29	30.74	76.90	28.80
49	0	92	45	89.37	42.41	91.92	42.63	93.84	47.16
50	31.0	103	58	100.65	54.59	105.58	56.53	108.46	63.00
51	0	114	68	111.92	66.77	116.48	69.06	118.83	74.24
51.25		116	73	114.74	69.81	118.92	72.04	121.01	76.60
52	0	125	81	123.20	78.95	125.70	80.67	126.87	82.95
52.25		126	83	126.02	81.99	127.82	83.45	128.63	84.86
53	0	135	91	134.48	91.13	133.78	91.58	133.44	90.07
53.25		136	93	137.30	94.17	135.66	94.22	134.91	91.67
54	3	144	101	145.75	103.31	141.02	101.96	139.00	96.10
54.25		147	104	148.57	106.35	142.72	104.48	140.26	97.47
55	0			157.03	115.49	147.60	111.88	143.80	101.31
56	0			168.31	127.67	153.66	121.43	148.05	105.97
57	0			179.59	139.85	159.29	130.67	151.85	110.03
58	0			190.86	152.03	164.56	139.64	155.28	113.75
59	0			202.14	164.21	169.52	148.35	158.42	117.15
60	0			213.42	176.39	174.22	156.85	161.30	120.28
61	0			224.69	188.56	178.69	165.16	163.97	123.17
62	0			235.97	200.74	182.95	173.28	166.46	125.87
63	0			247.25	212.92	187.03	181.24	168.78	128.39
64	0			258.53	225.10	190.94	189.05	170.97	130.76
65	0			269.80	237.28	194.71	196.72	173.03	132.99
66	0			281.08	249.46	198.34	204.27	174.98	135.10
67	0			292.36	261.64	201.84	211.69	176.83	137.10

DPRS = Days Passed in Rainy Season.

TABLE 2 ARTIFICIAL RECHARGING TESTS ON 28.10.04 FOR RECHARGE PIT-B

Cumulative Time (hr)	Recharging rate (cm/hr)	Water application rate (cm/hr)	Volume of water applied @ 0.294 l/s	Percentage of water applied for recharge	Volume of water recharge, liters
A	B	C	D=0.294*A	E=(B/C)*100	F=E*D
0.2	248.99				
0.3	145.65	347.75	317.52	41.89	132.989
0.4	103.34	246.74	423.36	41.88	177.312
0.5	80.16	191.36	529.2	41.89	221.680
0.6	65.49	156.39	635.04	41.88	265.930
0.7	55.37	132.17	740.88	41.89	310.377
0.8	47.97	114.57	846.72	41.87	354.519
0.9	42.31	101.01	952.56	41.89	398.999
1.0	37.85	90.45	1058.4	41.85	442.901
1.1	34.24	81.74	1164.24	41.89	487.687
1.2	31.26	75.36	1270.08	41.48	526.840
1.3	28.75	68.35	1375.92	42.06	578.752
1.4	26.62	63.12	1481.76	42.17	624.912
1.5	24.78	59.18	1587.6	41.87	664.764
1.6	23.18	55.28	1693.44	41.93	710.093
1.7	21.78	52.08	1799.28	41.82	752.464
1.8	20.53	49.03	1905.12	41.87	797.718
1.9	19.42	46.32	2010.96	41.92	843.110
2.0	18.43	44.03	2116.8	41.86	886.046
2.25	16.92	40.4	2381.4	41.88	997.359
2.5	15.16	36.16	2646	41.92	1109.330
2.75	13.68	32.68	2910.6	41.86	1218.391
24	2.0742				
48	1.0375				
72	0.6071				
96	0.4304				
120	0.3342				

TABLE 3 COMPARISON OF ESTIMATED WATER RECHARGING RATES (MM/HR) BY NATURAL AND ARTIFICIAL FLOW CONDITION

Days	Recharging rate for Pit A		Recharging rate for Pit B		Average recharging rate for Pit-A & B	
	Natural flow	Artificial flow	Natural flow	Artificial flow	Natural flow	Artificial flow
1	30.0	17.1 (43.0)	15.6	20.7 (32.7)	22.8	18.9 (17.1)
2	10.9	8.5 (22.0)	11.9	10.3 (13.4)	11.4	9.4 (17.5)
3	6.4	5.0 (21.9)	6.9	6.0 (13.0)	6.6	5.5 (16.7)
4	4.6	3.5 (23.9)	4.9	4.3 (12.2)	4.7	3.9 (17.0)
5	3.5	2.7 (22.9)	3.8	3.3 (13.2)	3.6	3.0 (16.7)
6	2.8	2.2 (21.4)	3.1	2.7 (12.9)	3.0	2.5 (16.7)
7	2.4	1.5 (37.5)	2.6	2.3 (11.5)	2.5	2.1 (16.0)
8	2.1	1.6 (23.8)	2.2	2.0 (9.1)	2.2	1.8 (18.2)
9	1.8	1.4 (22.2)	2.0	1.7 (15.0)	1.9	1.6 (15.8)
10	1.6	1.3 (18.8)	1.8	1.5 (16.7)	1.7	1.4 (17.6)

Note : Figures given in parenthesis show percent deviation from natural flow

ANNEXURE I

	Recharge Pit A	Recharge Pit B
	Year 2003	
Linear	Y= 110.16 + 9.06 X (r=94.97)	Y= 63.38 + 10.94 X (r=95.70)
Power	Y= 79.21X 0.37 (r=99.67)	Y= 101.95 X 0.29 (r=99.85)
Logarithm	Y = 97.09 + 42.40 ln X (r=99.81)	Y = 48.26 + 50.74 ln X (r=99.76)
	Year 2004	
Linear	Y=29.66+11.29 X (r=99.21)	Y=27.39+10.15 X (r = 99.77)
Power	Y=37.35 X 0.52 (r= 98.88)	Y= 29.17 X 0.62 (r = 99.77)
Logarithm	Y=32.34 + 33.44 ln X (r=97.42)	Y=24.07 + 33.81 ln X (r = 98.63)
	Year 2005	
Linear	Y=66.81 + 11.28X (r=99.57)	Y= 18.05 + 12.18 X (r =99.48)
Power	Y= 72.54 X 0.34 (r=99.65)	Y= 26.31 X 0.70 (r = 99.85)
Logarithm	Y=68.86 + 36.04 ln X (r= 98.52)	Y= 20.08 + 39.06 ln X (r = 98.78)

In these equations Y, X and r refer to depth of ground water table (cm), days passed in rainy season and coefficient of correlation, respectively.

ANNEXURE II

a. Values of coefficients of regression equations for estimated depth during application of water

Date of test	Stream size	A	B	r	Type of equation
28-10-04 (PIT-B)	0.2940 lps	160.9455 97.5876 104.6650	-44.3273 -0.5078 -49.8496	-97.2936 -49.8496 -98.3239	Linear Power Logarithm (selected)
25-10-05 (PIT-A)	0.4724 lps	120.9024 3.3158 -26.9951	-183.4135 -2.4714 -76.5621	97.8696 90.0585 99.4136	Linear Power Logarithm (selected)
26-10-05 (PIT-B)	0.5005 lps	134.8939 19.6739 27.1370	-100.5683 -1.5316 69.8660	94.9319 -94.2187 -99.6187	Linear Power Logarithm (selected)
27-10-05 (PIT)	0.9226 lps	143.8744 17.5315 14.9807	-143.0475 -1.1781 61.5928	98.9900 90.8793 98.1844	Linear Power Logarithm (selected)

b. Values of coefficients of regression equations for estimated depth during ground water recharging only

25-10-05 (PIT-A)	11.0155 57.1402 57.7097	43.1820 0.9060 29.6579	96.2965 95.1613 99.3317	Linear Power Logarithm (selected)
27-10-05 (PIT-B)	24.5831 108.7904 100.3023	83.8932 0.6699 35.9220	97.2566 99.4494 98.6341	Linear Power Logarithm (selected)